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MASTER

MEASUREMENT CONTROL PROGRAM FOR NDA INSTRUMENTS^a

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ABSTRACT

Measurement control checks for nondestructive assay instruments have been a constant and continuing concern at Los Alamos National Laboratory. This paper summarizes the evolution of the measurement control checks in the various high-resolution gamma systems we have developed. In-plant experiences with these systems and checks will be discussed. Based on these experiences, a set of measurement control checks is recommended for high-resolution gamma-ray systems.

I. INTRODUCTION

During the past several years, nondestructive assay (NDA) instrumentation has found increasing use in nuclear facilities for nuclear safeguards, criticality safety, and process and material control. It is generally necessary to base these instruments on a minicomputer or microprocessor system to achieve ease of operation in assayer interaction, data collection, data reduction, instrument calibration, and record storage. In some cases, this instrumentation is integrated into the overall special nuclear materials (SNM) control systems of facilities to give "real-time" nuclear material control. Because the NDA instrumentation often provides the input to the SNM accountability system, it is essential to have a well-designed quality assurance program of the NDA-generated assay results.

For many years, Los Alamos National Laboratory has been designing NDA instruments to be used in a variety of nuclear processing plants found in the fuel cycle. It is a constant concern at Los Alamos to develop useful measurement control (MC) checks to provide quality assurance of the instruments. Some of the instruments have been installed in plants and have been operated by plant personnel for as long as 10 years. During this period, much operational

experience has been accumulated about MC checks, which detect potential problems that, undetected, would degrade measurement reliability. This paper describes the evolution of the MC checks in the various high-resolution gamma systems (HRGS) we have developed.

II. EVOLUTION OF MEASUREMENT CONTROL

Table I lists the various HRGS we have developed and installed in plants over the years. The segmented gamma scan (SGS)¹ is one of the earlier systems developed to assay low-density scrap and waste. The Los Alamos SGS design incorporates a computer with 16-k words of memory, which is also used for the multichannel analyzer (MCA) memory. Because of limited memory, the only MC check built into the system is a daily check of the calibration constant. The SGS uses single-gain digital stabilization. Over the years we found that the system requires vigilance by the operators to check the resolution of the detector and the amplifier gain. Because the digital stabilization greatly reduces the gain drift, it is a highly desirable component for plant systems. The second HRGS, the uranium solution assay system (USAS),^{2,3} was installed at the uranium reprocessing facility at Los Alamos in 1975. The USAS has a gain check built into the computer program and also requires a uranium foil assay daily to check the calibration constants. The USAS monitors a pulser peak area for rate loss correction; the computer program therefore also checks the position of the pulser peak. These checks, though modest in scope, have been extremely useful during the past 8 years of plant use. Problems such as the drifting of the pulser voltage output in an environment where temperature may fluctuate as much as 20°F in one day, aging electronic components, and detector deterioration, were readily detected.

The solution assay instrument (SAI, first generation)^{4,5} consists of two different hardware configurations of the measurement principle developed by J. L. Parker.⁶ One SAI,⁴ based on a Data General computer with a custom-built MCA and assembly language programming, calculates

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TABLE I
MEASUREMENT CONTROL IN HIGH-RESOLUTION GAMMA-RAY NDA SYSTEMS

<u>System</u>	<u>Generic Check</u>		<u>Diagnostic Check</u>				<u>Plant Installation</u>
	<u>Accuracy</u>	<u>Precision</u>	<u>Gain-Zero</u>	<u>Background</u>	<u>Resolution</u>	<u>Peak-Ratio</u>	
Segmented Gamma Scan (SGS) ^a							1973-present
Uranium solution assay system (USAS) ^b	x		x				1975-present
Solution assay instrument (SAI)							
(First generation) ^c	x	x	(x)	(x)	(x)	(x)	1979-present
(Second generation) ^d	x	x	x	x	x	x	1981-present
TOKAI densitometer ^e	A		x	x	x	x	1979-present
Low solution assay instrument (LOSAI) ^f	x	x	x	x	x	x	1982-present

Note: x : This check is in the computer program.
 (x): This check may or may not be in the computer program (explanation in text).
 A : This check is done by administrative control.

^aRef. 1.
^bRefs. 2 and 3.
^cRefs. 4 and 5.
^dRef. 7.
^eRefs. 9 and 10.
^fRef. 13.

the short-term random error is within reasonable limits. The main features of these checks are

Accuracy Check

Purpose: Check against detector efficiency change, detector-to-sample position change.

Check: $T = (W_M - W_0)/\sigma_M$.
 W_0 = accepted value of stable standard or secondary standard.
 W_M, σ_M = measured value and sigma.¹¹

Precision Check

Purpose: Check against short-term fluctuations that may exceed the statistical fluctuations. Especially important if the system involves moving mechanical parts.

Check: Reduced $\chi^2 = S_n^2/\sigma_n^2$.
 S_n^2 = variance due to n repeated measurement.
 σ_n^2 = variance due to counting statistics.

The generic MC have been in use at the Los Alamos Plutonium Facility for several years. The wealth of information accumulated can be studied to determine the instrument performance in a number of areas and to determine the usefulness of the generic checks. Part of the study of this information is being presented elsewhere in this conference.¹²

Over the years we found that the generic MC did reveal mechanical problems such as a sticky shutter in the SAI (caused by the acid environment of the glove box). However, the generic MC can be satisfied even if (a) the detector resolution has deteriorated or (b) the system gain has shifted. The resolution degradation is caused by neutron damage, from increased electronic noise or by detector aging. The system gain shift may result from a faulty digital stabilizer or a gross gain shift that cannot be corrected by the stabilizers. The generic MC would not reveal these problems. In addition, the generic MC indicate problems but they do not indicate their origins.

In developing new instruments such as the SAI (second generation)⁷ and the LOSAI¹³ for the facility, we added the diagnostic MC to complement the generic MC. The diagnostic MC have been in use for about 2 years and have been valuable in revealing instrumental problems earlier than did the generic MC. The diagnostic MC shown in Fig. 1 detects the previously undetected errors mentioned above. There are two major differences between the generic and diag-

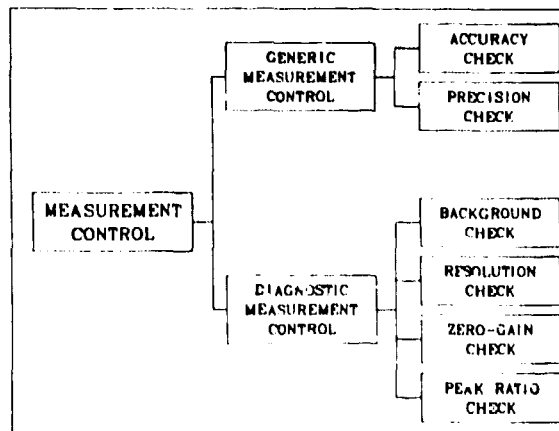


Fig. 1. Generic and diagnostic MC checks.

nostic MC: the diagnostic MC in general have no statistical basis, in contrast to the generic MC. The diagnostic checks are performed before the assay results are calculated, whereas the generic checks are performed after the assay results are calculated. Below is a description of the diagnostic checks included.

- (1) Background Check
 The need for this check is obvious. The background is measured daily. If the background counting rate in either energy region of interest exceeds predetermined limits, the assay chamber must be cleaned.
- (2) Resolution Check
 This check is performed on the two peaks used for gain and zero stabilization. Because the detector resolution depends on the gross counting rate, the limits are set at 20% above the resolutions of these two peaks at the highest expected counting rate. If these limits are exceeded, a warning message is given.
- (3) Zero-Gain Check
 This check is performed to ascertain that the zero and gain have not drifted from the original values. The check is performed on the two peaks used for stabilization. The limits are $\pm 1/2$ channel from the channels set on the stabilizers.
- (4) Peak Ratio Check
 This check is performed to reveal changes in detector relative efficiency and noise level. The limit is set at 3 sigma from the established ratio. This check was implemented in the SAI⁷ to indicate an

accidental movement of the detector relative to the sample chamber by measuring the ratio of the counting rates from the cadmium source fixed to the detector and the plutonium transmission source fixed in the shutter. The 414-keV (^{239}Pu) to 88-keV (^{109}Cd) peak ratios are checked. The ratio check has been found to be sensitive to other instrumental problems. First, a large increase in the electronic noise usually shows a different relative detection efficiency for a low-energy peak compared with a high-energy peak. Second, if the SAI shutter fails to open fully, the peak ratio will not be within acceptable limits.

III. RECOMMENDATIONS

The combination of generic and diagnostic MC checks has been applied to two HRGS plant instruments^{7,13} that have several years of plant operation. We found both the generic MC and diagnostic to be necessary and recommend their incorporation in all future high-resolution gamma-ray instruments from Los Alamos. Diagnostic checks are also being developed for neutron assay systems.

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